Inside INEEL

An inside look at the Idaho National Engineering and Environmental Laboratory

INEEL
Idaho National Engineering & Environmental Laboratory
BECHTEL BWXT IDAHO, LLC

March 2000

Seafood into 'super glue'

DOE laboratory clones mussel proteins to create natural waterproof adhesive

When the U.S. military was looking for a strong waterproof adhesive, scientists at the U.S. Department of Energy's Idaho National Engineering and Environmental Laboratory went straight to the experts—sea creatures that have been clinging naturally underwater for ages.

Mussels are the same delicacy often found next to the lobster and shrimp on a seafood buffet. The "feet" of the small mollusks produce an epoxy with adhesive-like properties that rival any "super glue" on the market. Unfortunately, it takes about 10,000 mussels or mollusks to produce just one gram of adhesive, resulting in a prohibitive cost, not only in dollars but to the mussel population.

So molecular biologists at the INEEL in Idaho Falls are developing methods to clone the mussel's genes, through DNA technology, that will allow them to economically produce large quantities of the adhesive protein. Because sea water breaks down even the strongest of conventional adhesives, a natural alternative is important to the Navy and private marine industry in building and repairing ships. The INEEL has a long history of work with the Navy, in part through the national security mission. Mollusks also attach to ships, increasing the drag, and therefore decreasing the efficiency at which these large vessels operate. Understanding the adhesive will help to prevent this marine fouling.

INEEL scientists are studying the edible mollusk Mytilus edulis, a form of mussel, to develop a bioadhesive that will stand up to underwater conditions.

The building industry also requires a stronger cementing element for manufacturing plywood, oriented strand and other building materials that deteriorate when subjected to water and moisture. Even the dental industry is looking for a better, safer adhesive for dentures, and medical disciplines such as surgery and orthopedics are interested in new suture and prosthetic technologies.

Mussels are able to cling to surfaces because they produce attachment threads called "byssal threads." The "foot" of the animal has organs that secrete protein with a catalyst. It takes about one minute for the viscous substance to harden into a thread, attaching itself to a new surface. It enables the mussels to anchor to rocks and pilings in turbulent areas where food and oxygen are more abundant.

The INEEL, in collaboration with scientists at the University of California, Santa Barbara, is identifying five proteins that go into the thread makeup that constitutes the "glue." Cloning the mussel proteins is expected to be the crucial step in opening doors for developing this amazing epoxy. "Right now, companies like 3M and Allied Signal would need about a million mussels just to start their evaluation," says Frank Roberto, a molecular biologist at the INEEL. "That's impossible to provide, but with a method of mass producing them through cloning," he adds, " industry giants will be able to test the natural super glue on their products."

The ability to remain intact in sea water is only one advantage the "mussel glue" offers. "It doesn't require high temperatures to activate its cementing qualities as do other conventional waterproof glues," says Roberto. "And, it's also environmentally safe because it comes straight from nature, unlike the standard petroleum and tar-based glues now being used," he adds.

(For more information, call Teri Ehresman at 208-526-7785.)

Mussels are able to cling to surfaces because they produce attachment threads called "byssal threads."

Representatives from INEEL meet with university researchers to discuss potential collaborative projects.

Collaboration brings new opportunities to the region

A unique collaboration of regional universities is expected to lead to enhanced opportunities for research, higher education and job creation throughout the Inland Northwest. Among the first anticipated impacts of the collaboration are advancements in environmental cleanup technologies.

Seven universities formed the Inland Northwest Research Alliance (INRA) in the spring of 1999. The member universities include Boise State, Idaho State, University of Idaho, Montana State, University of Montana, Utah State and Washington State.

INRA is a partner with Bechtel BWXT Idaho, the corporation responsible for managing and operating the Idaho National Engineering and Environmental Laboratory (INEEL) near Idaho Falls. In its managing role, INRA will help set the direction for scientific research performed at INEEL.

In the past the INEEL site was used for nuclear reactor research and storage of nuclear waste from America's defense programs which left contamination below the surface of the land. Today INEEL scientists work in a wide range of disciplines with a major emphasis on the development of environmental cleanup technologies. The site also is the U.S. Department of Energy's lead laboratory for developing nuclear technologies, performs work to support national security projects and finds new ways to coax energy from biological sources.

University of Idaho President Robert Hoover says INRA gives the institutions involved a chance to collaborate with the national lab on some major environmental problems. "The immediate goal will be to

*See **Collaboration,** page 2*

Human identity reduced to a barcode

Canned peas, beans, and human beings all have something in common—they can be identified with a barcode. It takes more than supermarket science to see a human's barcode, however.

The U.S. Department of Energy's Idaho National Engineering and Environmental Laboratory and biotechnology company Miragen have developed a technique that can display a "barcode" of antibodies that is unique for each person and may become a powerful new tool for law enforcement. National security is one of the DOE's key missions. The technique, called the Antibody Profile Assay (AbP™), can identify an individual by a subset of normally occurring antibodies present in the body called Individual Specific Autoantibodies (ISAs).

The actual test is just a strip of paper lined with bands of specific proteins that the ISAs can cling to. Researchers flush the test strip with blood or other bodily fluids, and then rinse it with reagents that stain the ISAs, creating a permanent, easy-to-read barcode. There is little sample preparation necessary, and the test can even distinguish between identical twins—something DNA testing cannot.

INEEL researcher Vicki Thompson wants to see this new technology become a tool for law enforcement. An important feature of the test is that it does not require DNA material, only bodily fluids. This will give law enforcement a very powerful new method for proving identity and presence at crime scenes. This past summer, Thompson demonstrated the technology to the City of Boise Police Department. The Department's response was enthusiastic. They have joined Thompson as collaborators with the Idaho and Utah State Forensic Bureaus in a joint research proposal submitted to the National Institute of Justice.

Thompson has engineered the test so that blood contaminated with dirt, dried on sidewalks and cars, or mixed with animal blood can still be accurately identified. The test can be prepared by someone with a high school education and takes only two hours to get results—a big advantage over DNA testing, which can take anywhere from 24 hours to three weeks or more. Her goal now is to document the validity of the test's accuracy so the technique may one day be used in court proceedings.

INEEL researcher Vicki Thompson prepares an Antibody Profile Assay.

(For more information, call Deborah Hill at 208-526-4723.)

COLLABORATION

Continued from page 1

develop new science that will help us understand the transport of materials in the subsurface."

The collaboration will also help each of the INRA universities meet education goals and advance scientific knowledge. "This is an opportunity for contracts and grants, to increase the research strengths of the member institutions. It is also an opportunity for graduate study and all the things we seek to do in higher education," says Hoover.

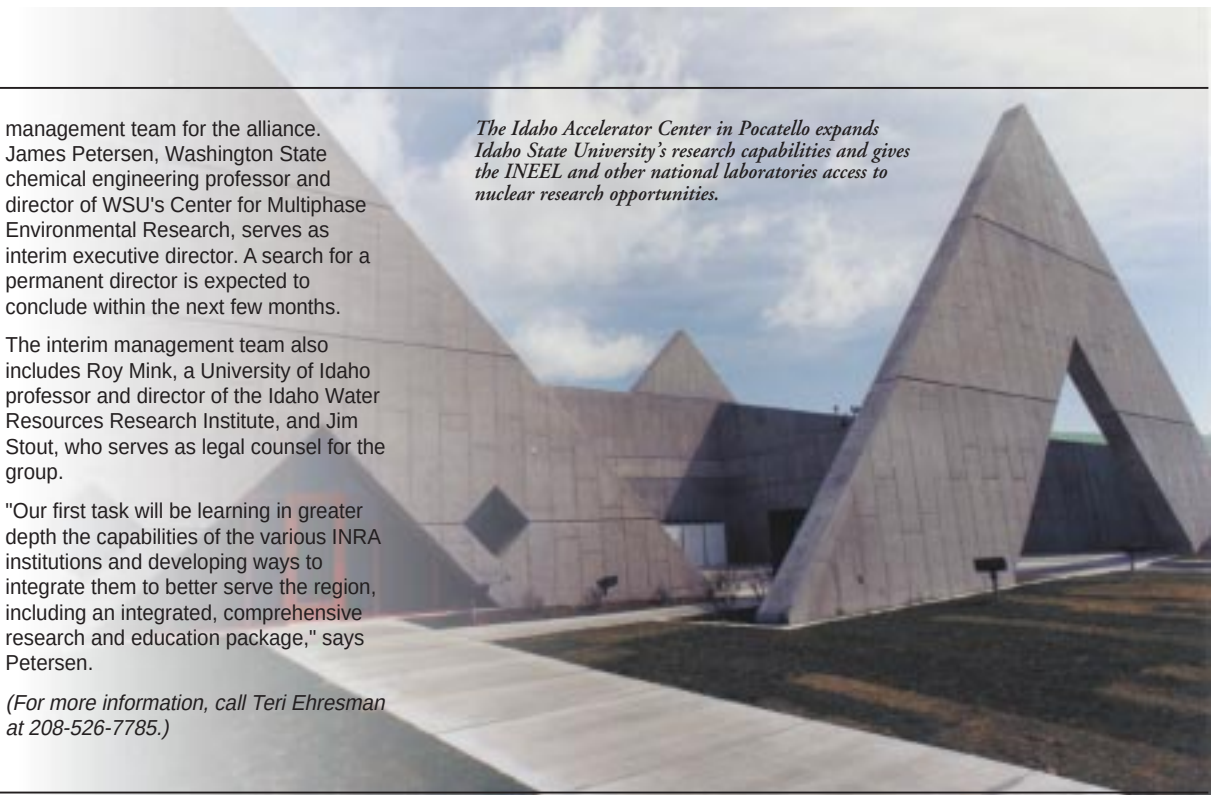
Over the next 10 years, INEEL expects to add some 1,000 Ph.D. positions. Many of these individuals will be educated by INRA institutions.

The presidents of the INRA schools recently appointed an interim management team for the alliance. James Petersen, Washington State chemical engineering professor and director of WSU's Center for Multiphase Environmental Research, serves as interim executive director. A search for a permanent director is expected to conclude within the next few months.

The interim management team also includes Roy Mink, a University of Idaho professor and director of the Idaho Water Resources Research Institute, and Jim Stout, who serves as legal counsel for the group.

"Our first task will be learning in greater depth the capabilities of the various INRA institutions and developing ways to integrate them to better serve the region, including an integrated, comprehensive research and education package," says Petersen.

(For more information, call Teri Ehresman at 208-526-7785.)



The Idaho Accelerator Center in Pocatello expands Idaho State University's research capabilities and gives the INEEL and other national laboratories access to nuclear research opportunities.

BBWI brings new focus to national science laboratory

The Department of Energy named Bechtel BWXT Idaho (BBWI) to lead the Idaho National Engineering and Environmental Laboratory into the 21st Century. BBWI became the managing and operations contractor on Oct. 1, 1999.

BBWI brings a new focus on how cleanup will be done at the INEEL and how to establish missions and areas of recognized laboratory expertise that fit within the DOE mission and ensure a long-term future for the laboratory.

BBWI includes Bechtel National, Inc., BWXT Technologies, Inc. and the Inland Northwest Research Alliance. INRA is an alliance of seven major regional universities in Idaho, Washington, Utah and Montana.

BBWI President Bernie Meyers says the company comes to the INEEL with three specific and critical goals: complete the INEEL cleanup on schedule, safely and cost-effectively; use science and research being done at the laboratory to support cleanup; and expand the INEEL's capabilities in three "thrust" areas to build a future for the laboratory. The thrust areas are establishing INEEL national leadership in subsurface geosciences investigation, continuing its nuclear and reactor technology research and expanding its energy efficiency research.

In a recent interview, Meyers discussed the challenges ahead for BBWI and stressed that environmental cleanup is the number-one priority.

"Nothing in our thrust areas will happen unless we do our cleanup operations, satisfy all tenets of the governor's agreement (the 1995 Idaho Settlement Agreement) and just do the work better than anyone else. If we convince everyone we can do those things, then the other things will come."

Meyers said that using INEEL scientific capabilities to achieve the cleanup is key. "We're going to do a science-based solution. We're going to use our scientists to figure it all out. If we work on our problems and solve them effectively, then the rest of the world will let us work on their problems."

Subsurface science will be a primary environmental research focus of the laboratory. Understanding how contaminants act and move underground and developing the technologies to trap them, stop their movement or remove them to protect the aquifer are important issues in Idaho and elsewhere.

"That's (subsurface science) going to be our signature. That's going to be where the world says, 'If you need subsurface geoscience done, there's only one place in the world to do it, and that's Idaho Falls," Meyers said.

Another area where the INEEL will build its future is pursuing nuclear technology research. Meyers said this continues the INEEL's 50-year heritage of developing safe nuclear power, and is a wise use of the existing expertise at the laboratory.

The INEEL will take a lead role in bringing the nuclear industry and universities together and developing the next generation of reactors that will satisfy concerns about safety, nonproliferation, economic and waste issues.

Finally, INEEL scientists will focus their research skills to develop alternative fuels and biomass technology to promote national energy efficiency — an area of INEEL research cited by Energy Undersecretary Ernest Moniz.

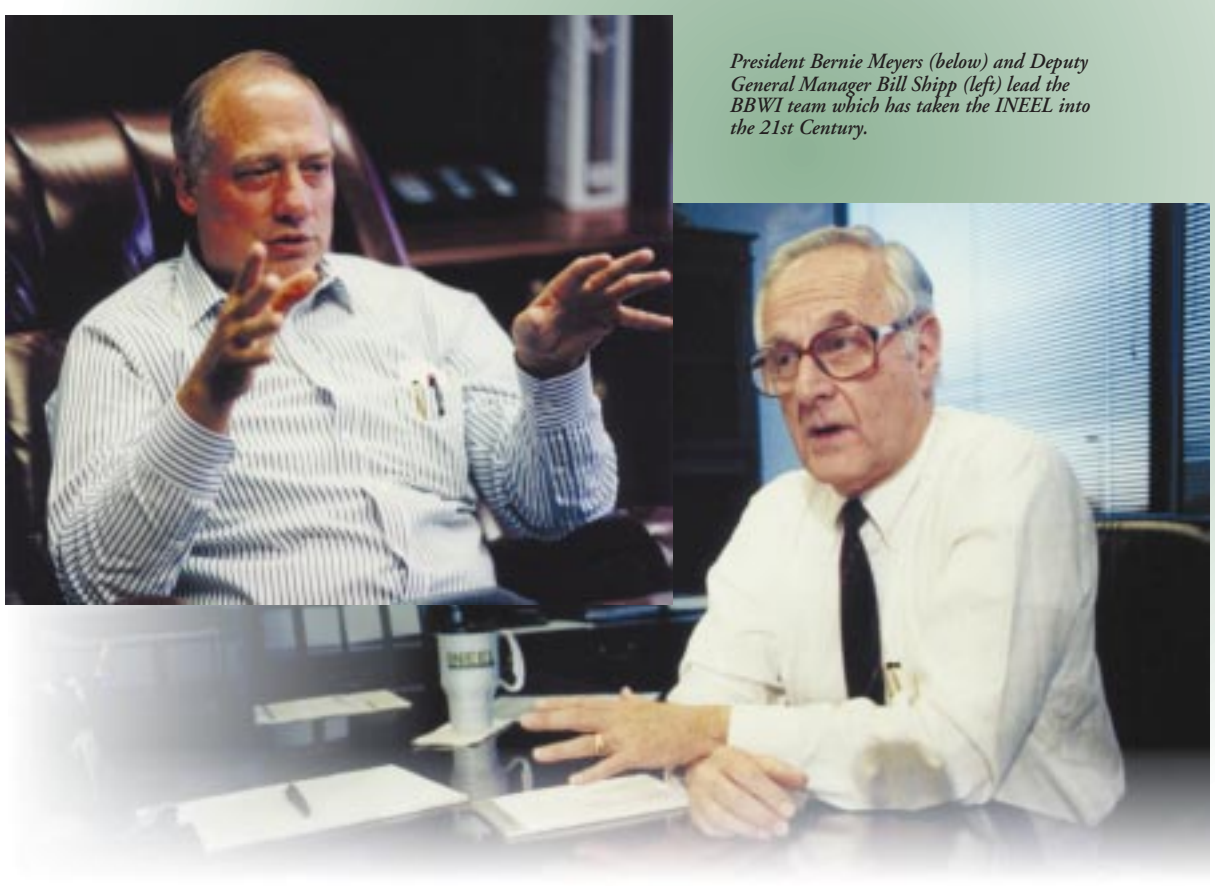
Beverly A. Cook, who took over last spring as manager of the DOE's Idaho Operations Office, commented, "I look forward to working with this team, and all the employees of DOE and the INEEL in meeting the challenges of completing our EM mission while, at the same time, developing the INEEL into a premier national laboratory which will continue to serve the nation's interests."

One key executive is Bill Shipp, BBWI deputy general manager and laboratory director and an internationally recognized leader in applied science and technology. Shipp's challenge is to build and promote the INEEL to the recognized status of other sustainable national laboratories such as Oak Ridge in Tennessee and Brookhaven in New York.

Idaho Gov. Dirk Kempthorne recognized his reputation and expertise and recently named Shipp the state's first science and technology advisor.

Shipp also is chair of the Science and Technology Advisory Council. Kempthorne noted that as the chair, Shipp will work with the state's universities to develop a state science and technology strategic plan that will help businesses throughout Idaho.

(For more information, call John Walsh at 208-526-8646.)



President Bernie Meyers (below) and Deputy General Manager Bill Shipp (left) lead the BBWI team which has taken the INEEL into the 21st Century.

Members of the BBWI team

Bechtel BWXT Idaho (BBWI) is made up of two companies and an alliance of seven regional universities. Each brings particular expertise and assets to the team.

Bechtel National, Inc. — part of the San Francisco-based Bechtel Group, Inc., a global engineering and construction organization. The company specializes in technical, management and directly related services to develop, manage, engineer, build and operate installations for customers worldwide. Bechtel built Experimental Breeder Reactor-I at the INEEL in 1950-51. EBR-I, now a registered national historic landmark, was the world's first reactor to produce usable electricity from nuclear power. For more than a century, the company has provided engineering, procurement, construction, management, development and financing services on more than 19,000 projects in 140 nations on all seven continents.

BWX Technologies, Inc. — a major operating unit of McDermott International Inc., BWXT supplies nuclear fuel and reactor components to the U.S. Navy, and high-precision manufactured components for other U.S. government and commercial markets. It also supplies products and services to operators of research reactors, operates and maintains U.S. government facilities, and provides cleanup and remediation of Department of Energy sites.

Inland Northwest Research Alliance—seven major regional universities—Idaho State University, University of Idaho, Boise State University, Utah State University, Montana State University, University of Montana and Washington State University. The alliance performs $300 million in research and development in 160 specialized areas for the Department of Energy, Department of Defense, National Aeronautics and Space Administration and other government agencies.

Fueling for the future

Researchers developing cheaper, cleaner, safer nuclear reactor fuel

As the world looks for sources of energy that won't contribute to global warming, interest in nuclear power is being rekindled. Projections for population and economic growth predict that by 2030, humanity could be pumping 60 percent more carbon dioxide—the gas most likely to cause global warming—into the atmosphere.

"Each 1,000-megawatt coal plant burns enough coal each day to fill a train a mile long," says Department of Energy's INEEL nuclear engineer Steve Herring. "A nuclear power plant prevents putting millions of tons of carbon dioxide into the air each year."

Nuclear reactors generate no carbon dioxide, but the nuclear power industry struggles because new nuclear power plants are more expensive than coal- and natural gas-powered plants. The difference drives up rates for electricity from nuclear power plants.

Hoping to increase the competitiveness of nuclear power plants, researchers from the Department of Energy's INEEL are leading an eight-institution collaboration to develop a new fuel that may increase the time nuclear reactors can run between shutdowns.

The researchers plan to improve the life of nuclear fuel by adding thorium dioxide to the uranium dioxide that currently powers commercial reactors. As the mixture undergoes a nuclear chain reaction, some of the thorium will turn into a type of uranium that can contribute to and sustain the reaction.

Using a battery of sophisticated computer programs to simulate the workings of a nuclear reactor, the scientists and engineers at INEEL will try to determine the optimal composition of the fuel. They will also study how the new fuel will behave in the core of a reactor.

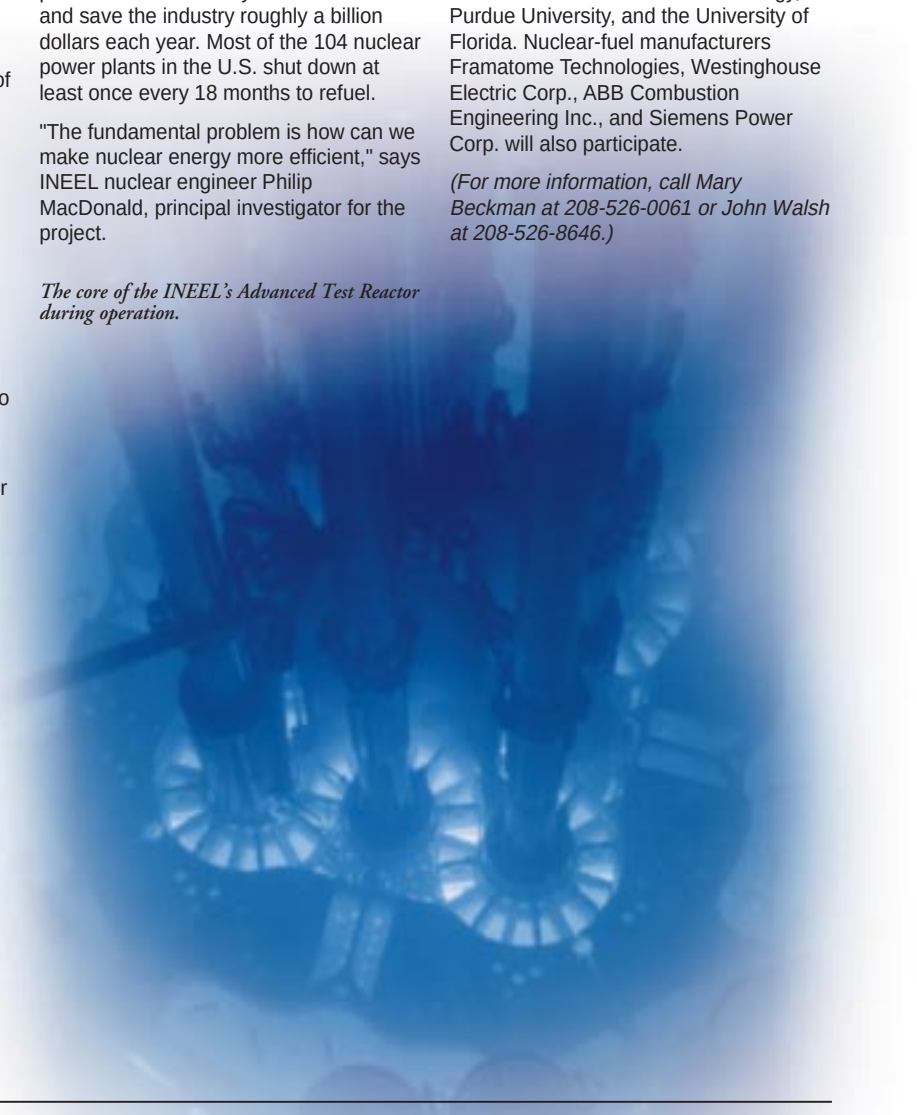
The researchers hope to double the time commercial reactors can run between refueling stops, which would allow nuclear power plants to produce five percent more electricity for the same cost and save the industry roughly a billion dollars each year. Most of the 104 nuclear power plants in the U.S. shut down at least once every 18 months to refuel.

"The fundamental problem is how can we make nuclear energy more efficient," says INEEL nuclear engineer Philip MacDonald, principal investigator for the project.

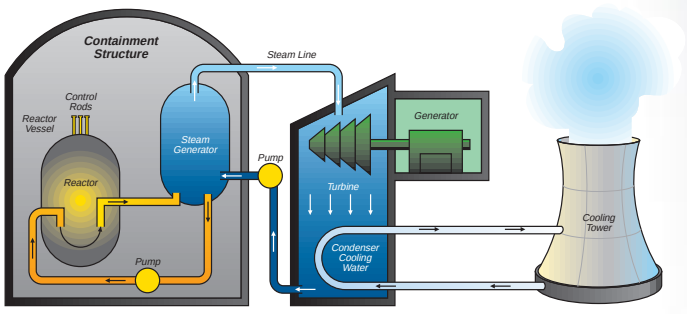
The other collaborating institutions are Argonne National Laboratory, the Massachusetts Institute of Technology, Purdue University, and the University of Florida. Nuclear-fuel manufacturers Framatome Technologies, Westinghouse Electric Corp., ABB Combustion Engineering Inc., and Siemens Power Corp. will also participate.

(For more information, call Mary Beckman at 208-526-0061 or John Walsh at 208-526-8646.)

The core of the INEEL's Advanced Test Reactor during operation.



In a pressurized water reactor, heat from the core is carried away by circulating pressurized water. The heat boils water in a second closed loop, and the resulting steam drives turbines that generate electricity.



Life in the inferno

Where microorganisms grow deep underground

Even Dante would blanch at the conditions kilometers below the earth's surface. Temperatures climb past the boiling point of water, pressures hundreds of times greater than our atmosphere bear down, and space is so tight even microorganisms can barely budge.

Yet, even there life persists. Now subsurface scientists have begun to identify the factors that determine how microorganisms survive deep underground in some places, but not others, say researchers from the U.S. Department of Energy's Idaho National Engineering and Environmental Laboratory and Princeton University. The INEEL specializes in subsurface science as part of its environmental mission.

Researchers know that heat-loving bacteria called extremophiles live embedded in rock thousands of feet below dry land, in deep ocean sediments and in fissures crisscrossing the ocean floor. "We're at the point of recognizing that microorganisms have remarkable abilities to colonize these environments, and we're trying to understand the factors that control that colonization," says INEEL microbiologist Rick Colwell.

A better understanding of how extremophiles survive deep underground may shed light on how life endured the earth's violent youth, or show scientists where to look for life on other planets, says Princeton geochemist T.C. Onstott.

Temperature appears to be the primary factor limiting how deep extremophiles can go. No known microorganism can live for long at 250 degrees Fahrenheit. Temperatures increase dramatically the lower you go underground and extremophiles should die off between three and four miles below dry land.

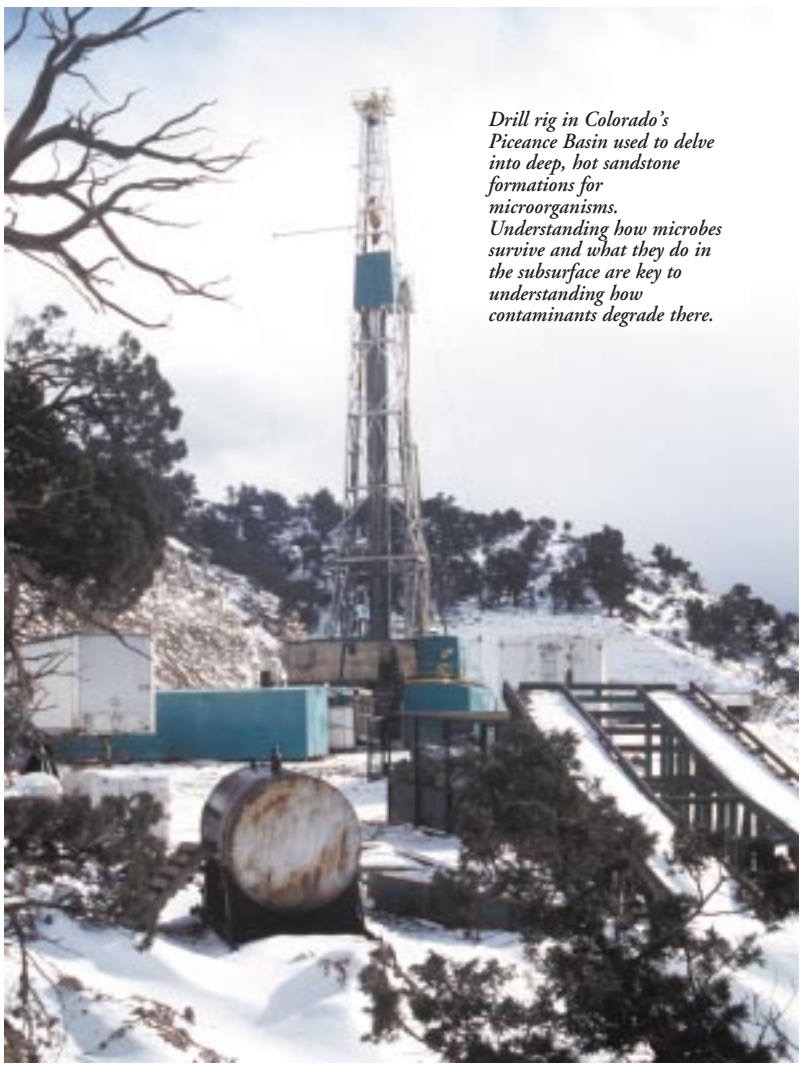
However, near geothermal hotspots, underground temperatures rise much more rapidly, and life may survive only near the surface. In deep ocean sediments, where miles of cold water above keep temperatures down, extremophiles may thrive at more than a mile below the ocean floor.

Pressure limits the range of extremophiles less than temperature does. Most microorganisms can survive at 600 times atmospheric pressure, which corresponds to a depth of over three and a half miles.

Lack of water and chemical nutrients likely prohibit deep subsurface life in arid, geologically stable regions. For instance, little grows between the surface soils and the groundwater of the Snake River Plain, on which the INEEL sits. However, extremophiles may be abundant deep in active geological features, such as faults, mid-ocean ridges and salt deposits, where fluids and nutrients flow more freely.

As data accumulate, researchers hope to understand the processes that control life deep below the surface well enough to predict where they will find it. "In the early days it was discovery-driven science—let's drill a hole and see what we find," Colwell says. Now, they have good ideas for where to look for life in Dante's realm.

(For more information, call Mary Beckman at 208-526-0061 or Teri Ehresman at 208-526-7785.)



Drill rig in Colorado's Piceance Basin used to delve into deep, hot sandstone formations for microorganisms. Understanding how microbes survive and what they do in the subsurface are key to understanding how contaminants degrade there.

Inside INEEL is published by the Idaho National Engineering and Environmental Laboratory Public Affairs Office for the U.S. Department of Energy. Questions and comments about this publication can be sent to *Inside INEEL*, P.O. Box 1625 MS 3695, Idaho Falls, ID 83415-3695, or call 208-526-7785.

Editor -- Teri Ehresman
Graphic artist -- David Combs
Writers -- John Walsh, Mary Beckman, Deborah Hill, Adrian Cho, John Howze, Isabel Valle-Carpenter

Inside INEEL is printed on recycled paper and can be recycled as white paper. For general information on the INEEL, call our toll-free line, 800-708-2680 or visit our web site at: www.inel.gov

An INEEL craftsman puts the finishing touches on a standardized fuel canister. These canisters will be placed in a shielded shipping cask which will be transported by rail to the disposal site.

INEEL designing safe spent fuel transportation system

The shipping container system that will be used to safely transport spent (used) nuclear reactor fuel from around the country for disposal at a federal repository is being designed at the Department of Energy's Idaho National Engineering and Environmental Laboratory.

The INEEL is the lead laboratory for the DOE's National Spent Nuclear Fuel Program. As lead lab, one of its responsibilities is to design a transportation system that can safely carry different types of spent nuclear reactor fuel from various DOE facilities and from commercial power plants.

The transportation system consists of an inner standardized canister, which fits inside a shipping cask.

The inner canister is cylindrical, made of stainless steel and has a variety of specially designed baskets securely holding the spent fuel rods that come in different shapes and sizes. The canister fits inside a shielded shipping cask, which will be licensed by the Nuclear Regulatory Commission. The cask will be transported by rail. Together, the two containers provide a system that offers radiation shielding and can withstand impacts during high-speed accidents, dropping, fire and immersion in water.

The inner canister must also be suitable for handling, storage, shipping and disposal. Using the same canister for shipping and storage promotes safety to workers, the public and the environment because it provides a sealed canister. It also reduces the number of times the spent fuel must be handled during loading, transporting, storage and final disposal.

The transportation system will be able to hold spent fuel of various shapes, sizes and makeup. The DOE has some 250 different types of spent fuel temporarily stored at facilities around the country.

The preliminary design was unveiled at a National Spent Nuclear Fuel Program strategy meeting last year and was well received by potential users. Test spent fuel standardized canisters were built by engineers and craftspersons at the INEEL and successfully drop-tested at the laboratory and also at the Sandia National Laboratory drop-test facility in Albuquerque, N.M.

Final canister design specifications will be completed in 2001 with the transportation cask system design completed by 2006. A private company will be contracted in the mid-2000s to manufacture the canisters. The standardized canisters and cask will be available for use by 2010.

(For more information, call John Walsh at 208-526-8646.)

INEEL, Argonne lead the way for DOE nuclear research

The Idaho National Engineering and Environmental Laboratory and Argonne National Laboratory are lead laboratories for the U.S Department of Energy in continuing nuclear reactor technology research and development.

That designation was made by Energy Secretary Bill Richardson in 1999, to recognize the laboratories' long-time leadership, technical expertise and critical facilities and infrastructure to support DOE's future nuclear energy needs.

Typifying its leadership role, last year the INEEL was awarded five research grants through the DOE's Nuclear Energy Research Initiative. NERI grants were awarded to eight other DOE laboratories, 21 universities, 16 private sector organizations and one other federal agency.

NERI supports innovative research to address key issues affecting the future use of nuclear energy in the United States. The projects selected under NERI include research in areas of proliferation-resistant reactors and/or fuel cycles, new reactor designs, advanced nuclear fuel, new technologies for management of nuclear waste and fundamental nuclear science.

The grants to the INEEL are for:

- A project to develop advanced nuclear reactor fuel that will reduce commercial power plant costs, increase reactor fuel life, reduce the amount of used fuel that must be disposed of and lessen concerns about fuel being diverted for weapons production. (See page 3)
- Research taking a new look at a generic design for an economical, safe, small light-water reactor based on current commercial power industry technologies and capabilities.
- A project to improve safety analysis and advance reactor design to let them operate at high efficiency levels and maintain safety.
- Research into a nuclear power plant safety analyzer that would evaluate safety requirements for power plants to find safety systems that may be unnecessary to ensure plant safety. Eliminating these unneeded systems could reduce construction costs and help promote future construction of new nuclear plants in this country.
- A project investigating new materials to be used for fuel cladding. (Cladding encases the reactor fuel.) New cladding materials would be needed in conjunction with new reactor fuels that are left in reactors for a longer time. The cladding material would have to stand up to extended use in a radiation environment along with the fuel.

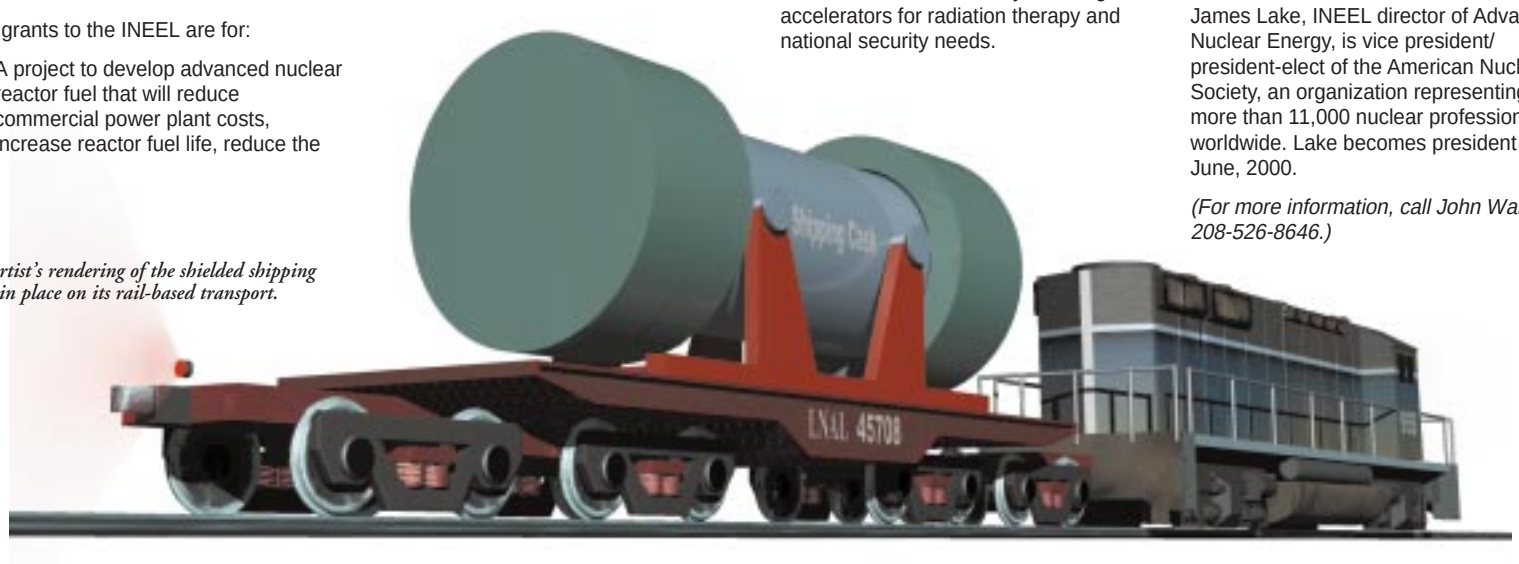
These components are part of a system being designed by the INEEL to safely contain and transport nuclear fuel.

The INEEL and ANL are collaborating in next-generation nuclear fuels through the Idaho Center for Fuel Development and Testing. The INEEL is also working with various universities. For instance, with the Massachusetts Institute of Technology, engineers are investigating advanced nuclear reactors that are safer, more cost effective, produce less waste and improve the proliferation resistance of the fuel cycle. The laboratory is also collaborating with Idaho State University on using accelerators for radiation therapy and national security needs.

INEEL researchers also have a number of ongoing projects in the Far East where nuclear power use is growing. Projects with the Republic of Korea and Taiwan are helping these countries develop the methods and capabilities to inspect, evaluate and ensure safety and performance of reactor systems, extend their life and perform the calculations to support reactor licensing decisions. These projects could open new business opportunities in Pacific Rim countries for the INEEL and represent a substantial worldwide responsibility for the INEEL to improve the safety of nuclear power.

James Lake, INEEL director of Advanced Nuclear Energy, is vice president/ president-elect of the American Nuclear Society, an organization representing more than 11,000 nuclear professionals worldwide. Lake becomes president in June, 2000.

(For more information, call John Walsh at 208-526-8646.)



An artist's rendering of the shielded shipping cask in place on its rail-based transport.

Microbial janitors tackle nuclear clean-up problems

Naturally occurring microbes are used to clean radioactively contaminated walls at a shut-down reactor in Sellafield, U.K.

Microbial janitors are helping their human counterparts with nuclear clean-up. U.S. Department of Energy's INEEL researchers, in collaboration with British Nuclear Fuels, plan to coax naturally occurring microbes to clean radioactively contaminated walls and ceilings at a shut-down reactor in Sellafield, UK.

The microbes' job is to eat and be merry—it's the corrosive microbial by-product that does the researchers' work. In this new technology, researchers whip up a batch of microbes and cellulose with a blender, and spice it with a dose of elemental sulfur. The end result is a vibrantly yellow gel with the consistency of the lemon curd you spread on a tea-time scone. The sulfur not only feeds the microbes, the bright color makes the gel easy to see, a plus when applying it to a surface for treatment. The gel is also very sticky, allowing researchers to apply the microbial colonies to any surface, including ceilings, without having it drip off.

Researchers spread the gel on the concrete and then raise the humidity around the gel to 95 percent. As long as the humidity and temperature are controlled, the microbes are able to work. As the microbes metabolize the sulfur, they create sulfuric acid. The sulfuric acid etches the concrete surface and loosens the contaminated layers.

When enough concrete has been loosened, researchers put the kibosh on the microbial feeding frenzy by dropping the humidity, causing the microbes to die off because they cannot tolerate ambient humidity levels. Then they vacuum the degraded concrete bits off the walls, ceiling or floor, and dispose of it. In laboratory tests, researchers have removed as much as 10-12 mm in a 12-month period of time.

The Sellafield proof-of-concept test run will help determine whether or not the technology is a good candidate for commercialization throughout Europe and the United States. This research has been funded through the INEEL's discretionary research program, the Department of Energy Environmental Management Program, and by BNFL through a cooperative research and development agreement.

(For more information, call Deborah Hill at 208-526-4723.)

Researcher becomes an accidental seismologist

Once you've seen the effects of an earthquake, it's hard not to ask – why can't we predict these things better? Well, two math-packed computer programs, a sandwich-sized piece of polycarbonate and a green-glowing laser may someday improve our understanding of the shuddering-slipping-cracking ground beneath our feet.

U.S. Department of Energy's INEEL mechanical engineer Eric Steffler experiments in materials physics led to a serendipitous connection to seismology. He set out to study how cracks and fracture systems develop in materials under mechanical stress. He developed a special kind of mechanical vice that can simultaneously squeeze, push and pull a material so that he could see how energy distributes around an existing crack as other fractures form.

One of the trickier parts of his experiment was creating gapless cracks in the material so that the crack face edges remain in contact with each other. This allows Steffler to see how friction affects the crack face displacements and subsequent crack growth. He uses two grids—a real grid stuck to the back of the test material, and a matching virtual grid created by a laser—to show how much surface displacement occurs during the test as more and more shear is applied. The real grid distorts along with the test material, and the virtual grid is the reference that shows how much distortion there is.

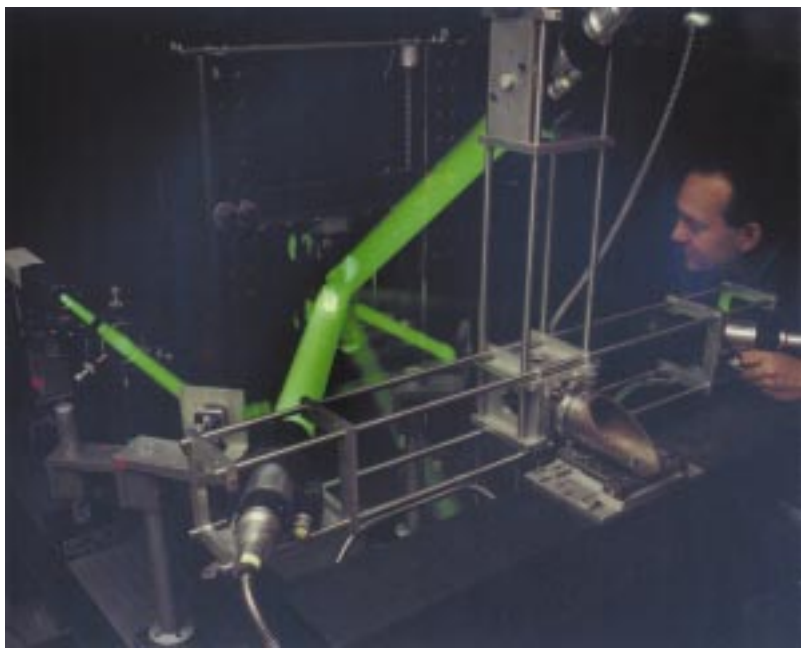
Steffler takes digital photos periodically during the crack test, feeds the data into two unique INEEL software programs and ultimately creates a grayscale image where each pixel is actually a data point describing surface displacement. With this data, he can create contour maps and graphs and perform a wide range of other analyses that describe progressive changes in shape.

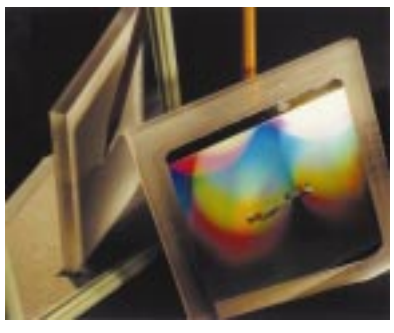
"I put together this experiment, and fully expected to see the data match up with standard stress predictions for materials. But they didn't, and I wasn't sure why," said Steffler. So he went back to the technical literature and looked outside the fracture mechanics discipline. He quickly discovered that the stress data he was seeing matched up with what geologists report along earthquake faults.

Steffler presented his data to geologist David Pollard and his research staff at Stanford's Geologic and Environmental Sciences Department. After their initial surprise, they were enthusiastic, Steffler said. In a three-hour test, researchers can see the complete progression of a fault and fracture system – something that would take decades to observe naturally.

The ability to study crack formation in real time may enhance earthquake prediction modeling. Steffler and Pollard are planning to collaborate in the future through the INEEL's discretionary research program. "That we have enhanced this analytical tool will be a good thing for fracture mechanics studies, but the fact that this can provide insight into the subsurface science area is fantastic," said Steffler. "That is a primary focus (in our subsurface science mission) of the INEEL."

(For more information, call Deborah Hill at 208-526-4723.)





During a fracture mechanics experiment, INEEL engineer Eric Steffler discovered his data resembled that of geologic faults. This enables the analysis of crack formation which could enhance earthquake prediction modeling.

Water's travels: The continuing saga of a seeping subject

Any meteorologist can tell you about the wind patterns over the earth. Under foot, however, is a different story. Just as the wind will distribute airborne dust around the world, so water will seep through the ground and carry with it nutrients, contaminants and even tiny microorganisms. But the subsurface is hard to access—subsurface scientists are at a buried disadvantage when compared with their meteorologist cousins.

Between the surface of the earth and the water table that is tapped by wells is a vertical area called the vadose zone. In southeastern Idaho, the zone can be up to 600 feet deep and is made up largely of a porous rock called basalt. In other regions of the country, the zone can be quite shallow—less than 20 feet in places—and made up of clay and other types of soil. These characteristics influence how water travels through the vadose zone and how contaminants interact with the subsurface.

Researchers at the Department of Energy's Idaho National Engineering and Environmental Laboratory are patiently gathering evidence of water's travels through various subsurfaces. Over the last several years, INEEL hydrologists Buck Sisson and Joel Hubbell have developed a remote, automated system to follow water traveling through the zone.

The equipment, usually positioned in wells at several depths to just above the water table, can measure two things automatically: the water content of the soil and the soil tension—or how tightly the soil holds water, an indication of how fast the water will percolate through the ground. Also, samples can be taken manually to test for contaminants of interest.

The centerpiece of this system is the award-winning Advanced Tensiometer, an electronic device developed at INEEL that uses an electronic pressure sensor to measure soil tension much deeper underground than conventional technologies allow.

Last spring, INEEL researchers set up the complete system around low-level radioactive waste disposal trenches at the Savannah River Site in South Carolina to examine water flow and to test for the radioactive element tritium. Over the summer, Sisson and Hubbell worked with Pacific Northwest National Laboratory's Hydrology Group to install Advanced Tensiometers at Hanford's Buried Waste Test Facility in Washington state as part of the Hanford Site Groundwater Vadose Zone Project.

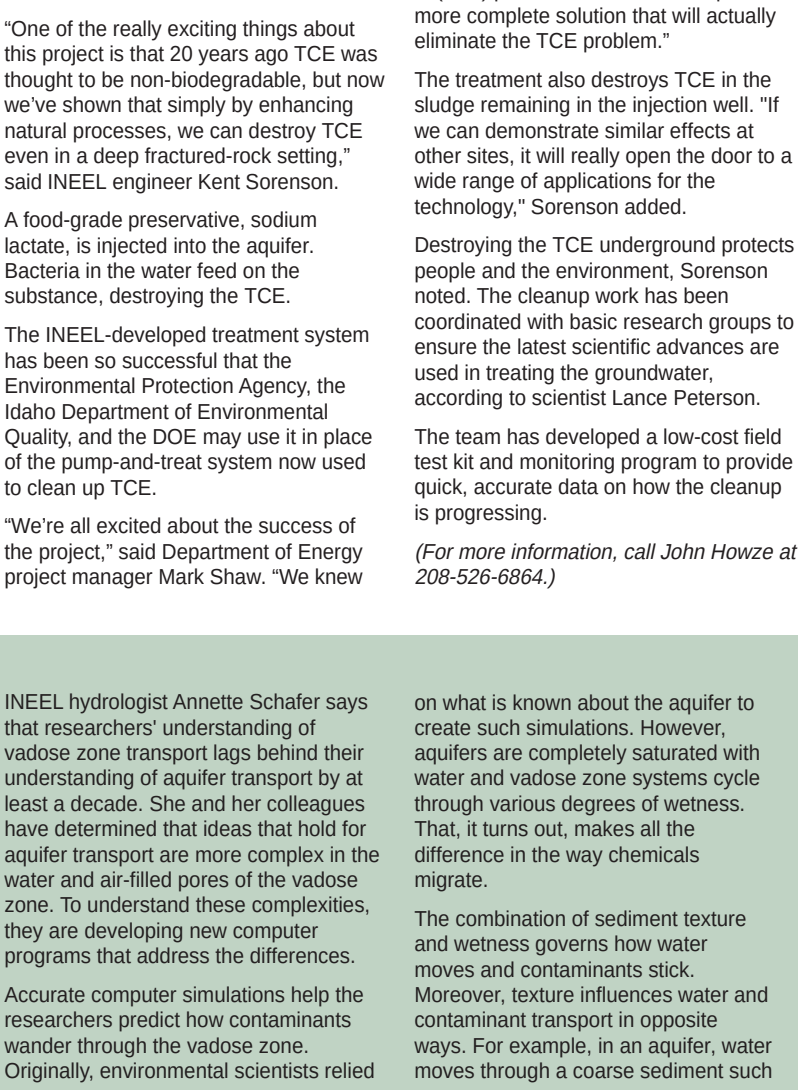
The six Advanced Tensiometers at Hanford were buried at intervals down to about 23 feet, less than a foot above a perched water table. There, they send their data automatically every hour to the above-ground data collectors. This will be the first time the Hanford researchers can monitor nearly continuously the water flow deep in the soil. They plan to compare data gathered automatically with that gathered by hand. Subsurface scientists will incorporate the vast amount of data that the automated system gathers into computer models that better predict water's path through various subsurface regions.

(For more information, call Mary Beckman at 208-526-0061.)

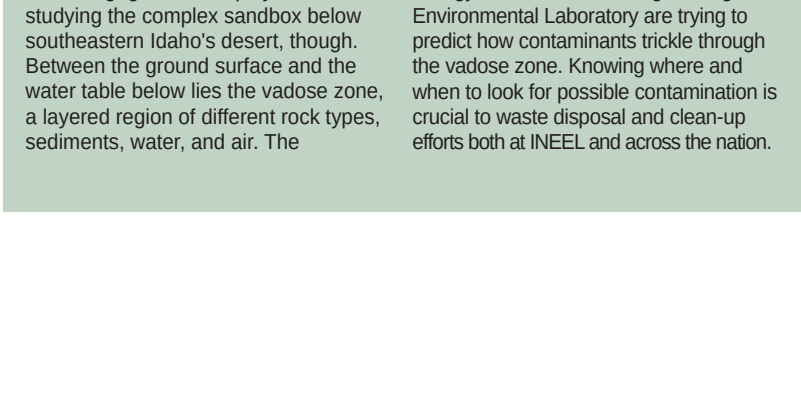
Buck Sisson, Jim Lee, and Joel Hubbell with their monitoring equipment.

Tensiometer equipment being lowered and lodged at the appropriate depth

The Advanced Tensiometer is capable of measuring the migration of water at a much greater depth than conventional technologies have allowed.



Bacteria science speeds cleanup of groundwater



Kent Sorenson stands by the pump and treat equipment that may soon be obsolete when INEEL's sodium lactate-based treatment system is in place.

In a world first, Idaho National Engineering and Environmental Laboratory researchers are cleaning up pollution deep in the aquifer beneath the INEEL, using resident bacteria.

Trichloroethene (TCE), a degreasing agent, is the problem. Once widely used by industry, TCE is now the most common groundwater contaminant in the United States.

"One of the really exciting things about this project is that 20 years ago TCE was thought to be non-biodegradable, but now we've shown that simply by enhancing natural processes, we can destroy TCE even in a deep fractured-rock setting," said INEEL engineer Kent Sorenson.

A food-grade preservative, sodium lactate, is injected into the aquifer. Bacteria in the water feed on the substance, destroying the TCE.

The INEEL-developed treatment system has been so successful that the Environmental Protection Agency, the Idaho Department of Environmental Quality, and the DOE may use it in place of the pump-and-treat system now used to clean up TCE.

"We're all excited about the success of the project," said Department of Energy project manager Mark Shaw. "We knew that pump and treat could keep the TCE problem from getting worse, but we also knew that it couldn't completely eliminate it. (This) process is a faster, cheaper, more complete solution that will actually eliminate the TCE problem."

The treatment also destroys TCE in the sludge remaining in the injection well. "If we can demonstrate similar effects at other sites, it will really open the door to a wide range of applications for the technology," Sorenson added.

Destroying the TCE underground protects people and the environment, Sorenson noted. The cleanup work has been coordinated with basic research groups to ensure the latest scientific advances are used in treating the groundwater, according to scientist Lance Peterson.

The team has developed a low-cost field test kit and monitoring program to provide quick, accurate data on how the cleanup is progressing.

(For more information, call John Howze at 208-526-6864.)

Zoning in on the Vadose Zone

Shakespeare had it wrong. All the world's a sandbox, not a stage. And as any kid can tell you, the sand is mixed in with dirt and rocks and clay, all of which influence how quickly the water sinks out of the sandcastle's moat.

Environmental engineers and scientists aren't engaged in kid's play when studying the complex sandbox below southeastern Idaho's desert, though. Between the ground surface and the water table below lies the vadose zone, a layered region of different rock types, sediments, water, and air. The composition of these layers regulates how water travels from the surface to the aquifer, and how contaminants that are along for the ride, such as from industrial, mining, and agricultural activities, make their way downward.

Researchers at the U.S. Department of Energy's Idaho National Engineering and Environmental Laboratory are trying to predict how contaminants trickle through the vadose zone. Knowing where and when to look for possible contamination is crucial to waste disposal and clean-up efforts both at INEEL and across the nation.

INEEL hydrologist Annette Schafer says that researchers' understanding of vadose zone transport lags behind their understanding of aquifer transport by at least a decade. She and her colleagues have determined that ideas that hold for aquifer transport are more complex in the water and air-filled pores of the vadose zone. To understand these complexities, they are developing new computer programs that address the differences.

Accurate computer simulations help the researchers predict how contaminants wander through the vadose zone. Originally, environmental scientists relied on what is known about the aquifer to create such simulations. However, aquifers are completely saturated with water and vadose zone systems cycle through various degrees of wetness. That, it turns out, makes all the difference in the way chemicals migrate.

The combination of sediment texture and wetness governs how water moves and contaminants stick. Moreover, texture influences water and contaminant transport in opposite ways. For example, in an aquifer, water moves through a coarse sediment such

*See **Vadose Zone,** page 7*

Using data from sites like this mine near Salmon, researchers hope to establish a gauge to measure soil cleanup progress.

A 95-course meal for microbes

Someday, fingerprinting may be just as useful for environmental scientists as it is for forensic scientists. Water bodies and soils contain populations of tiny unseen microbes. The kinds of microbes that live there change according to changes in the local environment. A microbial fingerprint could indicate the health of a contaminated stream or a plot of land on its way to being cleaned up.

Environmental microbiologists from the Department of Energy's Idaho National Engineering and Environmental Laboratory and their collaborators at Johnson State University in Vermont want to be able to characterize changing microbial populations in water and soil. To test their methods, they looked at how an old mine's presence affected the health of the microbial communities in a nearby stream. Environmental cleanup is one of INEEL's missions.

How do you tell if the populations of resident microbes are changing, staying the same or simply being wiped out? That would be easy to tell with humans -- they're big and easy to see. But microbes can't be seen with the naked eye, so the researchers have modified a method commonly used to type individual species of bacteria in laboratories called physiological profiling. By profiling communities instead of individual species, they've discovered some interesting things about the microbial health of streams tainted with mine drainage.

To identify the unseen communities, the collaborating researchers looked at what the microbial critters like to feed on, similar to identifying human populations on different continents by the greasy fast food, say, compared to spicy curried dishes they consume. Using a panel of 95 different foodstuffs called carbon sources, the researchers created a fingerprint of the microbial communities existing in different localized environments.

Tromping up to the No Name Mine near Salmon, Idaho, INEEL microbiologist Mike Lehman and colleagues sampled Iron Creek near the mine and a few spots downstream. "We expected the microbial communities near the mine to be much less active," says Lehman.

Instead, the profile showed a very robust community—the mine drainage microbes feasted on as many food sources as their cousins upstream. But when the researchers looked at the pattern of consumption, they noticed a large distinction between the communities. The different communities living in the drainage and downstream had different consumption fingerprints, indicating different microbe communities were at work near the mine compared to up and downstream.

Lehman hopes this type of profiling will be applied to environmental restoration of soils to gauge the clean up. "With soils, there's no real clean up criteria like there is for water," he said. "We want to be able to say about a site, 'Okay, it's clean,' or 'Okay, it'll function the way it's supposed to.'"

(For more information, call Mary Beckman at 208-526-0061.)

Helping to predict the life of a crack

No one would ever think to throw milk out before the expiration date, but many metal components of our country's infrastructure are thrown out while they are still useful. Pipes, bridges and storage tanks may crack normally with age.

Little is known about how long they will last after a crack has formed, or what conditions will worsen the crack to the breaking point. So little is known, the components get no accurate "expiration date." Out of concern of the potential consequences if cracked components give out, many structural components are taken out of service earlier than perhaps necessary.

Better ways to predict the life of a crack would likely extend the lifetimes of many structures. The American Society for Testing and Materials standards provide proven procedures for measuring everything from tire sidewall integrity to the toughness of cracked ceramics to the crack-resistance of folded leather. However, accurate models are not available to predict the life of a metal component containing a crack.

Researchers at the Department of Energy's Idaho National Engineering and Environmental Laboratory, in collaboration with the Massachusetts Institute of Technology, are developing a predictive technology that can be used to more accurately figure "expiration dates" for metal structures within both the civil and industrial realms.

This vessel was removed from a petrochemical plant after a crack formed. The instruments poised above the tank record crack growth as researchers pressurize the tank beyond its breaking point.

"This technology could be used to extend the lifetime of existing structures because we can more accurately estimate what the structure can handle," says INEEL materials engineer Walter G. Reuter. INEEL's expertise in nondestructive evaluation methods arises from its 50 years of experience with nuclear reactor safety.

Using data from nondestructive testing on full-scale metal structures—such as a tank removed from an industrial plant, Reuter and colleagues are developing Fitness for Service prediction procedures for natural cracks in welds. As part of this technology, they are developing ASTM Test Standards for measuring the "fracture toughness" of welds and metal objects with surface cracks—the higher the fracture toughness, the bigger the crack that the structure can withstand before it fails.

The researchers increase the pressures on tanks to speed up a resident crack's growth. Carefully detailing what conditions worsen cracks in different types of welds enables them to predict when cracks will cause the structure to fail in real life. The researchers are examining welds because the large majority of structural failures occur in these metal bonds, and surface cracks are the most common crack detected in structural components.

"We're learning how to fabricate the structures and welds, how to run tests on them, and how to evaluate the results," Reuter says. "There is a lot of need to be able to predict fitness-for-service in the aerospace and petrochemical industries—oil plants are getting old and new environmental requirements are being written."

(For more information, call Mary Beckman at 208-526-0061.)

Vadose Zone

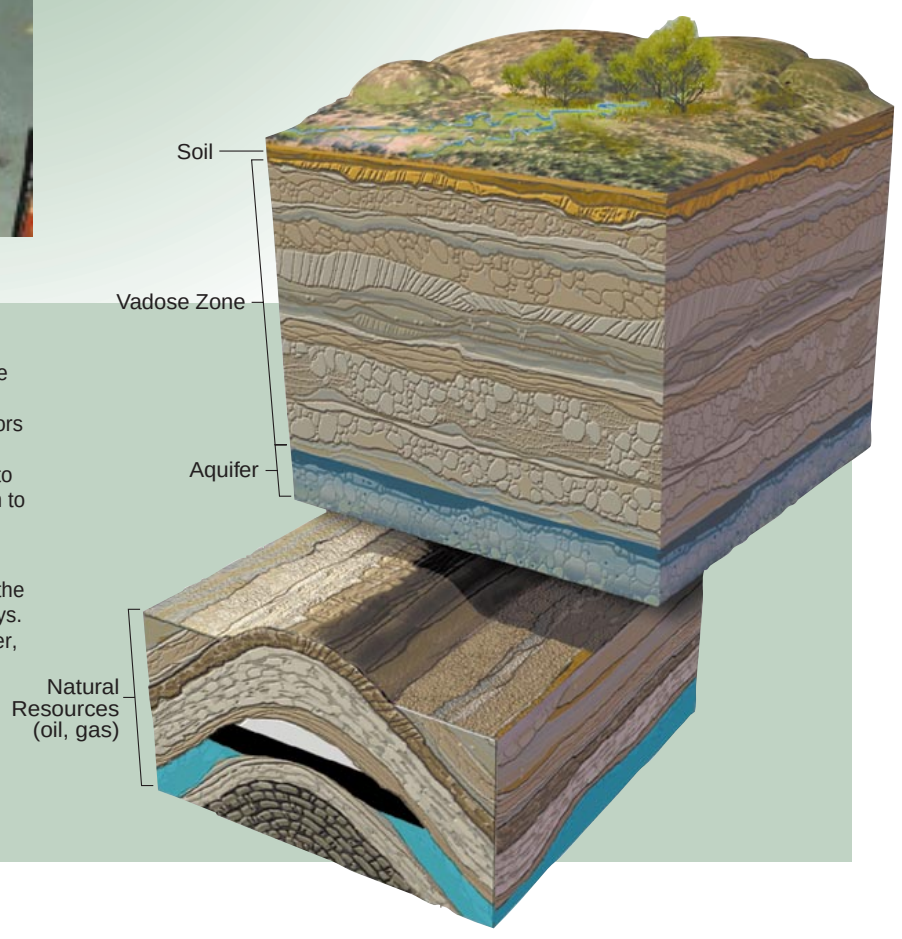
Continued from page 6

as gravel faster than it moves through a fine silt. However, silt's fine grains provide considerably more surface area with which contaminants can interact, slowing the migration of such molecules. In contrast, when the soil is initially dry as in the vadose zone, water moves faster in fine-grained sediments than in coarse ones.

Schafer is incorporating these concepts into computer programs of contaminant transport—both small-scale variation in sediment properties as well as the concept that the saturation levels change throughout the vadose zone, depending on moisture level and type of sediment. These factors have a profound influence on how researchers can expect contaminants to travel, Schafer says, but applying them to computer models of transport is in the early stages.

"These factors are just a little piece of the vadose zone transport puzzle," she says. "As we understand the processes better, our models will continue to develop."

(For more information, call Mary Beckman at 208-526-0061.)



The vadose zone is sandwiched between the surface soil and the aquifer, or water table.

In search of methane

INEEL microbiologist joins Japanese expedition to tap marine-methane deposits

After 14 grueling days on a drilling rig off the coast of Japan, INEEL microbiologist Mark Delwiche brought home his prize – two coolers full of frozen logs of mud. These core samples harbor stubbornly hardy methane-producing microorganisms that may eventually provide answers to the world's future energy worries.

Delwiche helped crew the drilling rig H.G. Hulme, Jr. in late November to secure deep subsurface core samples that will form the basis of his research for the following year. A Department of Energy INEEL microbiology team hopes to learn where methane-producing microbes prefer to live and why, and begin to understand how fast they produce methane. Delwiche's work on the drilling rig was co-sponsored by the Japanese Petroleum Exploration Company and the DOE's National Energy Technology Laboratory.

Drill heads like this are the business end of the entire drilling rig.

The desired microbial community—called methanogens—lives in a remarkably hostile world. Theirs is the domain of the deprived-frigid, anaerobic, high-pressure environments with little food trickling down from the surface and cramped living space in the pores of the sediments.

Once the coring began, Delwiche spent his days working hard—sometimes four hours on, four hours off—taking sample after sample, processing one meter at a time. "It was exciting to be in such a focused group of scientists like that. This is their life. The discussions in the small hours of the night, the back of the envelope calculations, the sketches and speculations were beyond compare. This is where the rubber meets the road," said Delwiche.

Being back on a drilling rig was like old times for Delwiche, who spent ten years doing such work earlier in his career. But round-the-clock work, cramped quarters with no privacy and only a tenuous connection to the outside world can wear thin. "I never got good at feeling like the environment on a drilling rig was very homey," jokes Delwiche.

This drilling rig off the coast of Japan was home to INEEL microbiologist Mark Delwiche while he gathered methane hydrate-bearing core samples.

INEEL researchers want to understand if there is a link between these microbial communities and deposits of methane hydrate—methane gas molecules trapped in ice—to determine whether hydrates could be a renewable resource for the future. The drilling site, on the landward rise west of the Nankai Trough, is in an area believed to harbor large amounts of gas hydrate and may possibly harbor extractable natural gas deeper down.

The DOE sponsored Delwiche's participation in the expedition to advance their fundamental understanding of methane-producing microbial communities for both environmental and energy reasons. The massive pockets of methane gas presently trapped in ocean floor and continental sediments could become an important energy resource as fossil fuel reserves are eventually exhausted. Additionally, methane gas is potentially a major contributor to global warming.

INEEL researchers are also collaborating in fundamental research on methane hydrates through the INEEL's discretionary research programs with Portland State University, Monterey Bay Aquarium Research Institute, Massachusetts Institute of Technology and the University of California at Berkeley.

Read Mark Delwiche's dispatches from the rig at http://inelext1.inel.gov/science/feature.nsf/ineel/delwiche

(For more information, call Deborah Hill at 208-526-4723.)

INEEL helps develop environmentally friendly hydropower turbines

To those who live in the Pacific Northwest, the issue of salmon in serious trouble has been discussed and debated for a long time. Up to 12 types of Pacific salmon and steelhead are currently listed as threatened or endangered under the Endangered Species Act. These include spring, summer and fall runs of chinook salmon, sockeye salmon, chum salmon and steelhead.

Immediate action is needed to reverse the declines of naturally spawning wild salmon, steelhead and other fish and improved habitat.

Among other things, dams create barriers to juvenile fish swimming downstream to the ocean. Juvenile salmon pass hydroelectric dams through three major routes: spillways, bypass systems or turbines. Juvenile fish can be injured or killed when they pass through powerhouse turbines at dams on their journey downstream. Salmon and steelhead that migrate from the upper parts of the Columbia or Snake rivers must traverse numerous dams on their journey to the ocean and return trip.

Fish passage is an important issue in the operation of hydroelectric plants. Current hydropower technology, while essentially emission-free, can have undesirable environmental effects, such as fish injury and mortality from passage through turbines, as well as detrimental changes in the quality (dissolved gases) of downstream water. Advanced hydropower turbine technology could minimize the adverse effects yet preserve the ability to generate electricity from an important renewable resource.

The goal of the U.S. Department of Energy's Advanced Hydropower Turbine System Program (AHTSP) is to develop technology that will allow the nation to maximize the use of its hydropower resources while minimizing adverse environmental effects. Conceptual designs of environmentally friendly hydropower turbines have been completed under the DOE-industry program.

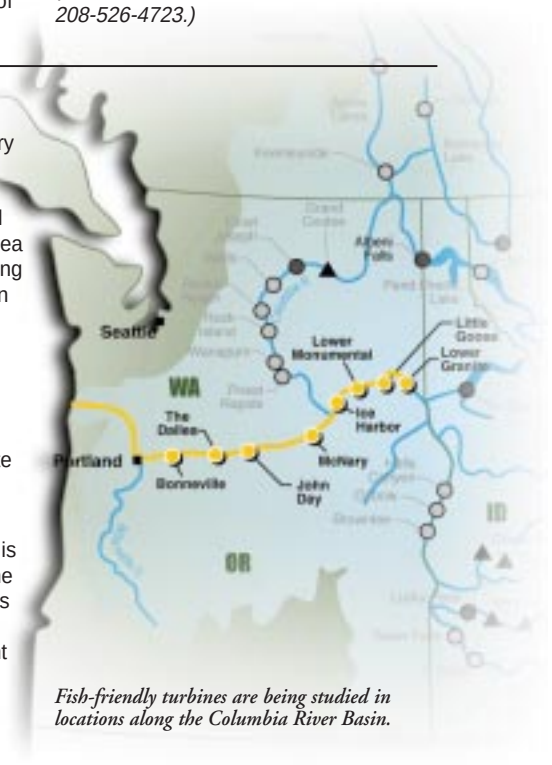
The Idaho National Engineering and Environmental Laboratory is the lead lab for the engineering aspects of the DOE program. Oak Ridge National Laboratory in Oak Ridge, Tenn. is providing the environmental expertise. Both labs are working with Pacific Northwest National Laboratory scientists in the Tri-Cities area of Washington state. They are conducting biological and hydraulic characterization tests.

Currently, potential injury mechanisms related to turbine passage have been identified and research is being performed to understand the effects on fish and to develop methods to eliminate the impacts.

There are many benefits of advanced turbine technology. One big advantage is reducing fish mortality. Advanced turbine technology could reduce fish kills to less than two percent, compared to turbine-passage mortalities of five to 10 percent for the best existing turbines and 30 percent or greater for some turbines.

Current tests at Bonneville Dam on the Columbia River demonstrated that the new advanced turbine design concepts may improve overall fish passage survival rates.

The development of an environmentally friendly hydropower turbine stems from the need to continue using a reliable source of renewable energy along with maintaining a healthy environment and a sustainable ecosystem. "We are losing hydropower capacity in this country and we are trying to maintain what we have," said Garold Sommers, advisory engineer/scientist, at the INEEL.



Fish-friendly turbines are being studied in locations along the Columbia River Basin.

(For more information, call Isabel Valle-Carpenter at 208-526-9906.)

Laboratory brings millions of dollars to region

The Idaho National Engineering and Environmental Laboratory contributes to research and development in science and engineering on a national and international level.

But within Idaho and the Intermountain region, the Department of Energy laboratory in Idaho Falls makes significant economic and social impacts in the form of taxes, purchases from businesses and community support. The scope of the INEEL's contributions is documented in the 1999 *INEEL Impacts* report. Compiled annually by Idaho State University's Center for Business Research and Services, the report provides information on the annual social and economic impact of the INEEL. The current report covers the fiscal year from October 1998 through September 1999.

Among the economic impacts, the INEEL purchased $97.8 million in goods and services from businesses in Idaho. While much of it was spent in southeast Idaho—$86.1 million—$7.1 million was spent in southwest Idaho, $3.5 million in northern Idaho, and $1 million in central Idaho.

The purchasing impact spread to bordering states: $17.3 million in Utah, $10.6 million in Washington, $4.4 million in Oregon, $4 million in Nevada, $500,000 in Montana and $100,000 in Wyoming.

Besides businesses purchases, the INEEL infused another $400 million into the Idaho economy. This came through 15,621 jobs in southeast Idaho directly and indirectly dependent on INEEL wages and salaries, retirement benefits paid to former INEEL employees living in the state, money spent by INEEL visitors on lodging and consumer purchases and economic diversification.

INEEL employees paid nearly $134 million in federal, state, Idaho sales taxes and Idaho property taxes in 1999.

Site employees also contribute significantly in money and time to community services. The Impact study reports, "According to estimates generated by Equifax Corporation, the average Idaho family annually contributes $1,551 to all causes. A recent personnel survey reveals that the average INEEL household contributes nearly twice that amount—an average of $2,926 per household." That is more than $21 million to charitable causes.

Additionally, the personnel survey indicated INEEL employees donated 1,386,949 hours of community service including church, youth, education and other community groups.

Copies of the 1999 *INEEL Impacts* report can be obtained from the INEEL Citizen Inquiry Line, (800) 708-2680.

(For more information, call John Walsh at 208-526-8646.)